beneath the notice of a man with a fair share of intellect and diligence.

And this opinion was quite justified by the facts. In my own University—London—until quite recently, there was no evidence of practical knowledge required in any branch of science except botany, for the degree of Bachelor of Science. A fair amount of mathematics and mathematical physics were demanded; but the chemical standard was miserably low, and the zoology, physiology, botany, and geology were such that no experienced examinee would wish for more than a month's reading for each, with perhaps an extra fortnight in the case of botany to enable him to learn enough of the art of describing plants. But now that a searching practical examination is enforced in these subjects, the degree has a real value—it is evidence that a man has done real work.

The case is very similar at Cambridge. Formerly, the Natural Science Tripos was a bye-word—a sort of back-door to a university degree. Now, thanks in great measure to Dr. Foster, the chances are that a man who takes high honours in that Tripos will be the intellectual equal of a high wrangler or of a high classic.

Considering that this regeneration of biological teaching began only about ten years ago in London and Cambridge, I think New Zealand is distinctly to be congratulated upon the fact that the first professor of biology in the Colony—my predecessor in this Chair, Captain Hutton—was also the first to inaugurate the true method of teaching that science in the Australian Colonies. It is by no means the least important debt which the Colony owes to Prof. Hutton, that he, having made his reputation as a systematic zoologist, voluntarily undertook the labour—no light one—of organising, in connection with his lectures, a class for regular practical instruction in comparative anatomy. I must confess to a slight feeling of disappointment at finding, on my arrival here, that the revolution I had expected to initiate was already well under weigh.

(To be continued.)

THE ELECTRICAL DISCHARGE, ITS FORMS AND ITS FUNCTIONS[1]

I.

If we knew as much about electricity as we know about sound or light, we should be still a long way from having learnt all that we could wish, but we should know far more than we do now.

For instance, in the matter of sound, we know, in most cases, the nature of the air-disturbance to which it is due, and the mechanism whereby that disturbance is effected; and we have ascertained the magnitude and character of the aërial waves on which sound is carried. We know, in fact, what it is which is transmitted, and the velocity and direction in which that transmission takes place.

Again, in the matter of light, although we do not know the exact nature of the disturbance to which luminosity is due, nor the mechanical process by which that disturbance is effected; although we are not even certain whether the ætherial waves, to which light is attributed, have an actual existence or not, we nevertheless do know that something which is capable of being represented by wave motion is transmitted along a ray of light; its direction is a matter of simple observation, and we have determined the velocity with which it travels.

But when we come to electricity our knowledge is much more at fault. We know, it is true, how to produce electricity or electrical action, as well as how to transmit it, by means of wires, to a distance; we know also that there is a dissymmetry at the two ends or "terminals" of a battery or machine, or other source of electricity, implying a directional character either in that which is transmitted, or in the mode of its transmission. But we know neither what electricity really is, nor the process whereby it is transmitted. And although, on account of the dissymetry above mentioned, we cannot divest ourselves of the idea of direction, yet we have as yet no certain clue to the actual direction in which the transmission can be said to take place. It has, indeed, been shown, by the late Clerk Maxwell and others, that the mathematical expressions for the properties of a medium, whose vibrations are capable of representing the phenomena of light, are the same as those of a medium whose vibrations are capable of representing those of electro-magnetism; and that, on the supposition that light is an electro-magnetic phenomenon, the velocity of propagation of electro-magnetic disturbances is the same as the velocity of light. But an identity in the mode of mathematical representation does not decide anything about the physical facts in either case, nor does it even prove that the facts are the same in both cases. And lastly, even granting that there is actual motion along the wires, neither the mathematical formulæ nor the experimental facts can as yet decide whether the motion, or "current" of electricity, is to be considered as starting from one terminal and arriving at the other, or as starting from the second and arriving at the first; or, indeed, whether the motion may not be in some sense double, in both directions at once.

In this somewhat unsatisfactory state of ignorance we approach the subject of this evening's discourse. And although I cannot hope in any adequate sense to resolve these difficulties, I propose to explain what progress has been made towards a solution of them, and to indicate the direction which appears to offer the best promise of success in the prosecution of further research.

Into the various modes of producing electricity it is not my intention now to enter. I shall use them indifferently as may be most convenient, explaining only in general terms any differences which may be of consequence for understanding the various experiments shown in illustration of my argument. It will, in fact, be assumed that electricity has been produced by some known means or other, and our object will be to examine it in the course of its passage, with a view of obtaining some information as to its nature and its mode of transmission.

As a matter of fact we have here as our sources of electricity, first, a Holtz machine, or, rather, Prof. Töppler's modification of it), which produces electricity in a condition similar to that given off by the ordinary frictional machines, although it effects this by a different method; secondly, a battery, or arrangement of metallic plates and acid, wherein a flow or "current" of electricity is produced by the action of the acid upon the metal; thirdly, a dynamo-machine, such as those invented by Gramme, Siemens, Brush, or others, which produces a current similar to that from the battery, but by means of the expenditure of mechanical force in moving coils or other closed circuits of wire within the influence of an electro-magnet, or, as it is usually termed, within a magnetic field; fourthly, a magneto-machine by De Meritens, producing, on a principle similar to that involved in the dynamo-machine, a series of currents, but with permanent magnets, and in this case in alternate directions; fifthly, an instrument called an induction-coil, the object of which is to produce from currents of one character currents of another, in a way to be presently described; and, lastly, we have Leyden jars or condensers for accumulating large charges in a manner which will allow of their being discharged all at once.

Now, in the first place, suppose we make use of the battery, or of the dynamo-machine, producing a direct and practically uniform current; then, if the wires carrying the current be closed, no directly visible effect is produced. I say "directly visible" because indirectly we can prove that a wire carrying a current is in a condition different to one not carrying a current. One way in which this may be shown is the following:—If we bring an ordinary piece of copper wire into the neighbourhood of some iron filings, the filings are indifferent to its presence when it is in its natural state; but as soon as the wire is made part of a circuit through which a current is flowing, the filings are attracted by it as if by a magnet. When the circuit is broken, so that the current is interrupted, the filings drop, and the wire resumes its ordinary condition. This property of a wire carrying a current is, however, beside our present purpose, and I mention it only in order to show that the passage of an electric current is not without its effect on a closed circuit, even when no result is directly visible.

The magnetic effect which we have just seen is not, however, the only effect which a current produces in a closed circuit. If in a galvanic circuit, supposed to consist otherwise of copper wire, we interpose a piece of different metal of a kind called refractory on account of its bad conductive power, such as platinum or iron, or a sufficiently thin piece of the same wire, we shall find that when the current is passing, the interposed wire becomes hot; and if we increase the strength of the current, or reduce the thickness of the wire—in other words, if we increase the quantity of electricity flowing through the platinum, or diminish the size of the platinum conductor which has to carry it—we shall find that the temperature is proportionally increased. A similar increased temperature will be produced by

[1] A Lecture delivered before the British Association at York on September 5, 1881, by William Spottiswoode, D.C.L., LL.D., President of the Royal Society.

shortening the wire, although the explanation of the phenomenon is not quite so simple. If the same process be carried further, the platinum will become white-hot, and if it be carried still further, the platinum will be fused. The Swan, the Maxim, the Lane-Fox, and the Edison lamps, in which the light is due to the incandescence of a fine thread of carbon, are beautiful instances of the application of this principle.

The platinum, which does not allow the electricity to pass along it with the same facility as the copper, is said to offer "greater resistance" than the copper of the same thickness to the passage of the current; and if we were to measure by a suitable instrument the quantity of electricity which passed through the circuit when the platinum was interposed, and were to compare it with that which passed without the platinum, we should find that the quantity was diminished by the interposition of the platinum. The energy which, as electricity, disappears in its passage through the platinum is, however, not really lost, but reappears in the form of heat.

Instead, however, of interposing in the circuit a length of resisting metal, we may break the circuit altogether, or (to express the same thing in different words) we may interpose an interval of air. In such a case the electricity will no longer flow freely as it does through copper, or even push its way as it does through platinum, but it will traverse the interval only in a disruptive manner in the form of a flash or spark; and it is to be noted that the interval over which the passage can be made to pass, or length of spark, does not depend, at least in a direct manner, on the quantity of electricity employed or "strength of current," but rather upon the quality of it. This quality is called "tension," and it is measured by the strength of current which it can maintain, or cause to flow, through a given resistance. The force called into play in the process is called "electro-motive force." Without attempting to go fully into the subject, we may illustrate the relation of quantity or strength of current to tension or electro-motive force in general terms by reference to the instrumental means requisite for their production. Thus it is usually stated that in a battery the quantity depends upon the size of the plates employed, and the tension upon the number of cells; and similarly, that in a magneto- or a dynamo-machine, the quantity depends mainly on the thickness of the wire used in its construction, and the tension upon the number of convolutions or length of the wire in the coils for a given speed of working, or for a given number of convolutions, upon the speed at which the machine is driven.

In further explanation of this, however, it should be pointed out that the current generated has, independently of the external circuit, to pass through the cells of the battery, or through the wires of the machine, both of which offer resistance. When a strong current is required, this resistance may be diminished by increasing the size of the plates in the case of the battery, or by increasing the diameter of the wires in that of the machine. In the latter case it must be borne in mind this increase in diameter usually involves a diminution of length on account of the necessary limitations in the dimensions of the machine, and consequently also of electro-motive force. This must be compensated either by increasing the speed of the machine or by augmenting the strength of the field magnets.

With the Holtz machine the matter is a little different. The quantity of electricity produced depends on the amount of surface of the revolving plates passing in front of the collectors in a given time, and consequently for a given machine upon the speed at which it is driven. Thus there is nothing either in the construction of the machine nor in its internal working which can alter anything except the quantity of electricity produced, and we must therefore look to the circumstances and mode of discharge for a determination of the tension of the electricity evolved.

The induction-coil is an instrument for producing from currents of large quantity and low tension others of high tension, but of small quantity. It consists mainly of two parts, viz. a primary coil of thick wire and few convolutions, through which intermittent currents are sent from a battery or machine; and a secondary coil outside, but not connected with the former, of fine wire and many convolutions, through which by a kind of sympathetic or "inductive" action temporary currents are set up every time a current begins or ceases in the primary. The tension of the induced currents depends fundamentally upon the length of wire or number of the convolutions in the secondary coil. There are several other parts of the instrument which are important for its working, which, however, it is not necessary for our present purpose to particularise.

From this digression we may now return to our main subject; and taking it up again at the point where we left it, viz. the heating of resisting metals, we may vary the experiment by taking a piece of iron wire, and bringing to bear upon it some of the induced high tension currents from the induction-coil. It will now be found that if the sparks follow one another with sufficient rapidity, the wire will not have time to cool during the interval between two successive sparks, and that it will burn like a match or other combustible substance.

If, however, we use, instead of iron, some metal very difficult of fusion, or "refractory," as it is called, such as iridium, the consumption of material will be extremely small; and in the incandescent terminals we shall have a source of light of considerable power. And further, if the terminals be inclosed in an envelope impervious to air, and either well exhausted or partially filled with suitable gas other than oxygen, nitrogen for example; then the loss by oxidation will be reduced to an insignificant amount. On this principle Mr. Gordon has constructed a lamp, which consequently has, at all events, the scientific interest of occupying a position intermediate between the incandescent and the arc lamps.

Lastly, if we accumulate a large quantity of electricity in a Leyden jar, and discharge it all at once through a thin wire or film of badly conducting metal, we shall cause the metal (in this case a strip of gold leaf) to be not only fused but to be shattered or deflagrated, in the manner which you will immediately see. The image of the gold leaf is now thrown on the screen, the jar is charged by currents from the induction coil, and is discharged through the metal. The gold leaf is now shattered by the passage of a high tension charge, the quantity of which is greater than it can carry; and in the image of its remains we may trace indications of the forces which have been at work in the process of destruction. Observe, in particular, how the particles have been thrown laterally outwards, as if by an explosion from inside the gold leaf. In the alternations of range of the laterally scattered particles Mr. De La Rue traces an analogy to the phenomena of striation described below. And if these alternations are not due to diversities in the conducting power of the wire at various points, but to resistances set up periodically by the discharge itself in its passage, the two phenomena must certainly have something in common.

I do not, however, propose to pursue these forms into greater detail, because the subject to which I wish more particularly to draw your attention, as the most fruitful both in results actually obtained and in promise for the future, is the passage of the discharge through air and other gases. And I have adduced these experiments with metallic substances in order to show that the discharge through them is capable of various modifications, analogous to those which we shall presently see in gaseous media.

Turning then our attention to gases, it will be convenient, for instrumental and other reasons, to invert the order of experiments, so as to begin with the form of discharge which corresponds to the deflagration experiment, and to proceed thence to less violent forms.

We will now make use of the Holtz machine. If, while the instrument is in action, we separate the terminals to any moderate distance, the discharge will take the form of a bright spark extending usually in an irregular line from one terminal to the other. If, instead of discharging the machine or coil in this manner, we charge a Leyden jar, and then discharge it; or if, what is substantially the same thing, we insert a Leyden jar in the circuit, allowing it to become charged and to discharge itself, then the discharge is of a character similar to that above described, except that it is shorter in span, and at the same time more brilliant in illumination. This is due to the greater quantity of electricity discharged at once. It is moreover to be observed that, however great the quantity of electricity passing in this manner, the discharge appears to be absolutely instantaneous. It is moreover a curious circumstance, attested by many experiments, that the form of discharge in which a Leyden jar is used appears to be incompetent of itself to communicate heat to even inflammable bodies. Thus, such a discharge will pierce a card without leaving any signs of charring behind; and it will disperse a heap of gunpowder, through which it passes, like a heap of sand, without exploding it. It may be added that gun-cotton itself, even in a state favourable to explosion, when exposed to a discharge of this kind, is not only not ignited, but

merely shows signs of perforation like the card, without any blackening or indication of combustion. Whether these facts point merely to shortness of duration in the discharge such as to preclude the communication of heat-vibrations to the bodies traversed, or whether they imply some mode of motion with which heat has nothing to do, are questions which have been thrown out by those who have studied the subject.

In favour of the former view it should be stated that the spectrum of the spark proper, whether with or without the jar, shows bright lines, indicating the presence of metallic vapours. These of course imply a high temperature, although not necessarily any great quantity of heat. And if the duration of the spark itself be extremely small compared with that of the interval between two successive sparks, the period of cooling will be extremely long compared with that of heating, and the observed result is exactly what we might expect.

There is, however, one feature of the spark discharge proper which is perhaps especially deserving of remark, namely, the similarity, in appearance at least, of its passage through air with that of a spark through glass or other solid and non-conducting substances. In the latter case we are familiar with the manner in which it rends its way by a shattering and dislocation of the substance in its immediate path, while it leaves the other parts of the substance untouched, very much as does a bullet when shot through a pane of glass. The path, however, if of any considerable length, is never quite straight, and it sometimes divides itself into two branches. The analogy above suggested will be complete, and the phenomenon will be brought into harmony with other known facts, if only we regard the spark as being so rapid, so instantaneous, in its passage that the particles of air have not time to exercise their mobility during the period occupied by the spark in its passage through them. In this view, air itself in the presence of the electric spark is to be regarded as exhibiting a rigidity and brittleness comparable with that of glass itself.

If, the Leyden jar having been removed, the terminals of the

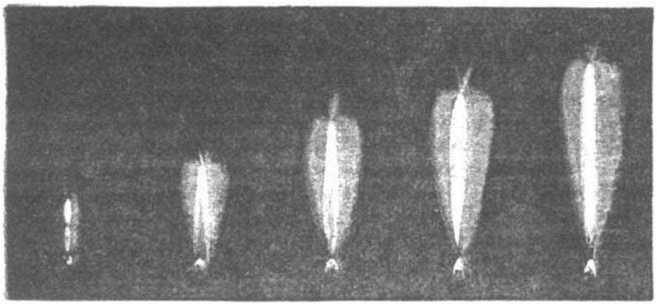

FIG. 1.

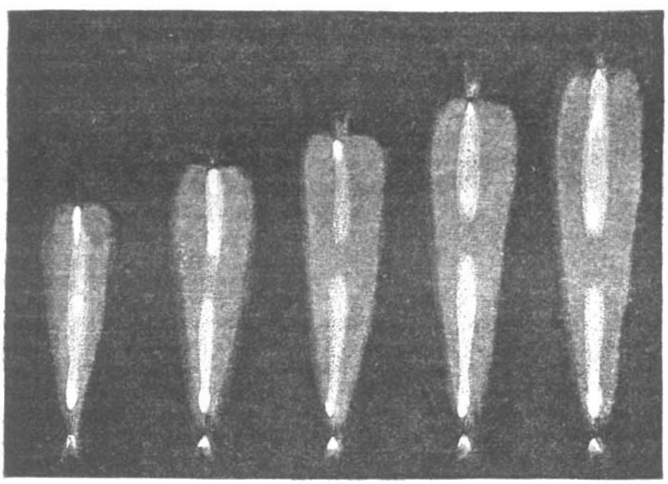

FIG. 2.

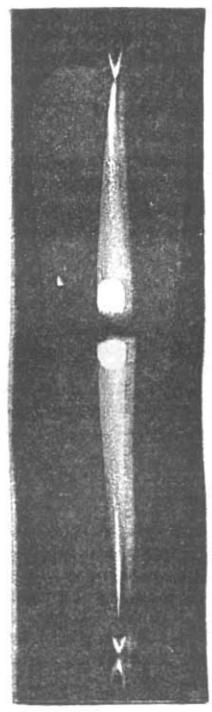

FIG. 3

Holtz machine be separated to a distance greater than that over which the spark will leap, a hissing or crackling noise is heard, indicating a rapid intermittence in the discharge, and a delivery, so to speak, of small quantities of electricity at a time. A minute examination of the phenomena occurring with terminals of different forms, and at different distances, has led to a classification of types of discharge under four main heads :—

1. The glow discharge: presenting a glow on the positive terminal, and a pencil of light issuing from the negative, and consisting of two portions with a dark space between them.

2. The brush discharge: consisting of a brush, viz., a stem and branches at the positive terminal, a pencil of light at the negative, and a dark space as before.

3. The band discharge: consisting of a band of light proceeding from the positive terminal, sometimes stratified, and separated from the negative glow by a dark space.

4. The spark discharge: showing in the spectroscope bright lines at both terminals. Two brushes of metallic vapour, that at the positive terminal being the longer, that at the negative the shorter and thicker. Two dark spaces are to be noticed in this form of discharge.

On the other hand, if the terminals be brought nearer together than they were at first, nearer, that is to say, than is suitable for the production of the spark proper, it will be noticed that the sharp cracking noise is replaced by a sound similar to that heard when they were beyond striking distance. The intermittence of the discharge becomes very rapid, and its colour assumes a reddish hue.

A full explanation of this almost abrupt change in the character of the discharge would probably involve a more profound acquaintance with the nature of electricity than we at present possess. But there is reason to think that something like the following takes place :—The path between the terminals once opened offers for a very short time considerable facility for the

electricity to traverse it again. But the distance between the terminals being very small, the electricity coming from the machine soon attains the requisite quantity and tension, and the discharge is repeated before the facilities due to the preceding discharge are lost. The shortness of the interval between the terminals consequently acts in a double manner to facilitate the discharge, and thus renders the transition from one form to the other more rapid than it would otherwise have been.

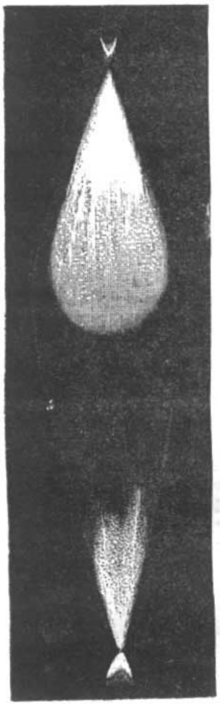

FIG. 4.

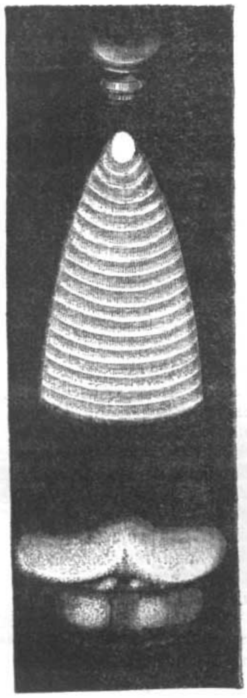

FIG. 5.

Observations with the spectroscope indicate that heating here takes place, and the revolving mirror shows that either in the discharge itself, or in the heating effects due to it, there is a manifest duration, all of which tend in the direction of the explanation suggested above.

The character of the discharge from the induction-coil both when the terminals are widely separated and when they are near together, is generally similar to that from the machine; but the durational character of the former is very much more marked than that of the latter; so much so, in fact, that with large coils the duration extends over a fraction of a second, perfectly appreciable by the eye without any auxiliary apparatus. This is due to the nature of the instrument, and is dependent both upon the time occupied by the core in losing its magnetism, and also upon the mutual induction of the convolutions of the secondary coil. The flame which accompanies the spark proper is the part of the discharge which persists; and it will have been noticed particularly when the coil is excited by the De Meritens' machine. The discharge produced from the secondary through the instrumentality of this machine is so remarkable, that it has been considered worth a special study. It has also been of great assistance in the examination of the action of a magnet upon a discharge; but the results of the latter experiments have not yet been published.

The form of discharge which we have now reached is substantially that which is known as the "arc," or comparatively quiet and continuous discharge between two terminals near to one another.

Turning to the arc, let us take the form most familiar to our minds, viz. that used in electric lighting. I now project on the screen an image of the arc as used in what are called "arc lamps." The whole consists essentially of two rods of carbon placed end to end, with a short interval between them. The interval is of a length capable of being traversed by the current, at all events after the discharge has been once established. By the passage of the current, which, in fact, constitutes the arc, the carbon becomes heated to a high degree. And it is important to understand that the main source of the light is to be found, not in the arc proper, but in the heated carbons. It will be noticed that, when a machine giving direct currents is used, the two carbons are not equally heated, and that during the combustion they acquire dissimilar configurations. This dissymmetry at the terminals is found to obtain in almost every species of electrical discharge.

With the construction and outcome of the various machines employed for producing the current, and with the mechanical contrivances used for maintaining the arc at its proper length and in its proper position, we are not here concerned. All that need be here mentioned is that the carbon which would be connected with the copper element of a Grove battery, if such were used, and which is called the positive, is the one more rapidly consumed. It becomes hollowed out, and incandescent particles may be seen occasionally traversing the arc, and landing upon the second or negative carbon. In the meantime the arc proper flows steadily between the carbons, the colour being determined by the nature of the terminals, or by that of any substance placed on their ends; and partly also by the nature of the gas in which the discharge takes place.

Let us now regard the terminals merely as parts of our apparatus, subsidiary to the main purpose, and fix our attention almost exclusively on the arc itself. If we had been working in the laboratory, I should have asked you to examine, with the aid of a microscope, the minute structure or anatomy of the arc. As it is, I must beg you to accept as a substitute for the phenomenon itself the following series of photographs, for which we are indebted to the skill and kindness of Mr. De La Rue, who has done so much with his unrivalled battery in this field of research.

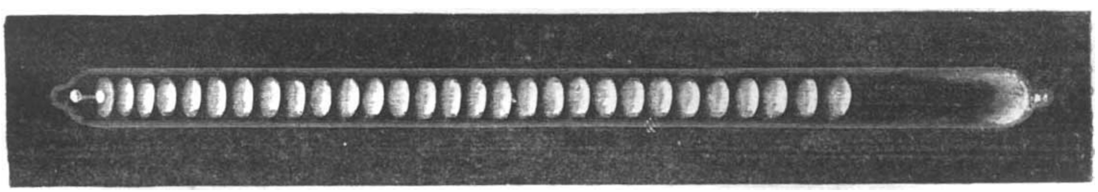

FIG. 6.

Figs. 1 to 5 are, in fact, magnified representations of the discharge through air at different pressures, beginning with that of the atmosphere, and extending in a series of decreasing pressure to about one 300th part of it. In Fig. 6 the pressure has been reduced to about a 2000th part of an atmosphere. In all these instances it will be noticed that there is a tendency on the part of the luminosity to break up into disconnected blocks, and that at an early stage it begins to separate from the negative, and to cling to the positive terminal. Also, that when the pressure is considerably reduced, these blocks are replaced by the beautiful system of flakes or "striæ" delineated in the last figure of the series. At this stage the dyssymmetry on which I have already insisted is complete.

The actual length of the discharges of which you have just seen the representations, varies in a tolerably regular manner with the pressure, from half an inch to ten inches or more. From this we may gather the important fact that in the discharge through gases at low pressures we have a magnified image of the discharge at higher pressures. By this statement it is not of

course intended that every detail that is observable in the former cases can be distinguished in the latter; for the very nature of the gas, its viscosity or other properties, may prevent this. But all the characteristic features which prevail at high pressures are found also at low pressures, on a larger scale and in more marked delineation. From this consideration, as well as from others to be noticed below, we are led to the conclusion that rarefied gases form a promising field for future research into the nature of the electrical discharge.

Proceeding on this basis, I now desire to present to you the actual discharge in two or three tubes from which the air has

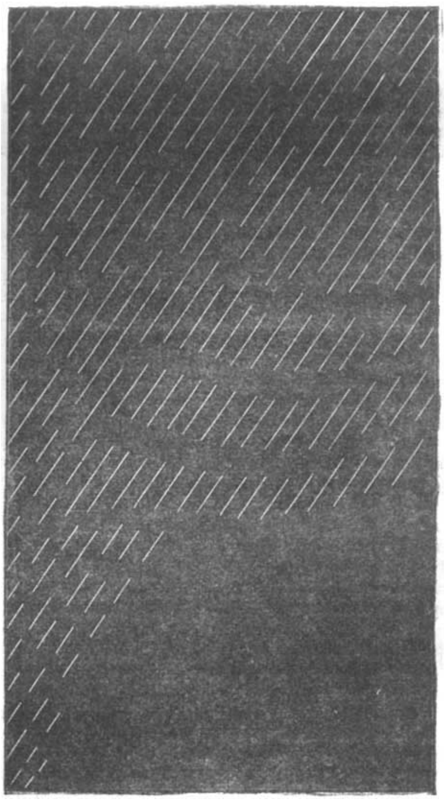

Fig. 7.

been exhausted in various degrees. In the first, where the pressure is that of about 3 or 4 mm. of mercury, or ·004, say one twenty-fifth part, of that of the atmosphere, the discharge takes the form of a column of light, slender in breadth and flexible in shape, extending throughout the entire length of the tube. The colour of the discharge depends on the nature of the residual gas. In the present case that gas is air; and the reddish hue is due to its constituent, nitrogen.

In the next tube the exhaustion has been carried further, viz., to a pressure of about 2 mm., or ·0026, say one-fortieth part, of an atmosphere. In this case the luminous column has become thicker; there are traces of a dark interruption towards the negative end; while beyond this break, and about the negative terminal, the light is no longer red, but of a deep blue colour. This strong contrast of colour at first sight appears inexplicable, and as a matter of fact the difficulties of explanation have not yet been altogether surmounted. But these difficulties are much diminished by a spectroscopic examination of the phenomena, from which it appears that, notwithstanding the contrast between the light near the negative terminal and that in other parts of the tube, the spectrum of the former differs from that of the latter, generally, not in its fundamental character, but mainly in the addition of certain strong lines in the blue and violet. Besides this, there is occasionally a weakening of the lines in the less refrangible part of the spectrum seen in the light of the positive column. The extension of a spectrum in the direction of the more refrangible end is known generally to depend upon an increase of temperature; and as there are other grounds for attributing a higher temperature to the region near the negative terminal than to the other parts of the tube, it would seem that we must look to thermal conditions for an explanation of the contrast in question.

But, besides the contrast just described, some tubes show a diversity of colour in the same striated column. Or perhaps, more strictly speaking, there coexist two, or even three, columns (usually pink and blue, with an occasional intervening green) blended together near the positive, but more separated towards the negative end. At the negative end they are in some cases completely separated; in others they are united so as to give the appearance of parti-coloured striæ. In every case, however, the blue striæ are found nearer to the negative end than the green or pink.

In the next tube the pressure is about half a mm., or ·00065, say one 160th part of an atmosphere; and here we find the dark space near the negative terminal, observable in the previous case, greatly increased. But besides this, the whole column is no longer continuous, but is broken up into striæ with dark intervening spaces.

As the exhaustion proceeds the striæ become more and more separated, as well as individually thicker. At first mere flakes of light, they gradually increase in thickness, until they assume the proportions of blocks of light sometimes of larger dimensions in the direction of the axis of the tube than in that of the diameter. At the same time the main dark space between the head of the column and the solitary luminosity about the negative terminal, as well as the dimensions of that luminosity itself, increase in length. A dark space immediately surrounding the negative terminal, and limited by the solitary stria, also begins to show itself, and to increase with the exhaustion. This space has been named after Mr. Crookes, who first made a study of it. As we proceed yet further, the column retreats towards the positive terminal; and at the last stage the solitary luminosity shares the same fate. The Crookes' space occupies the whole tube, and no gaseous illumination whatever remains. To the phenomena which arise in this condition of things I will make allusion at a later stage.

This dependence of the distance between the striæ upon the pressure of the gas may be well illustrated by using a tube fitted at one end with a chamber containing potash. The potash has the property of absorbing gases of almost every kind, of giving them out when it is heated, and of re-absorbing them when it is allowed to cool again. This process may now be seen in actual operation.

The number and disposition of the striæ will naturally depend also on the length of the tube. The effective length may be altered without altering any other conditions of the experiment, by having one terminal attached to the wire leading into the tube by a flexible spiral wire; so that the terminal itself may be shifted. At first sight it might have been supposed that any change due to an alteration in the length would have depended very much upon whether the shifting terminal is the positive or the negative. But whichever be the case, the striæ are seen to drop one after another into the positive terminal; the solitary stria and the adjacent dark space remain unaltered, and no change is apparent beyond a reduction in the number of the striæ.

This is, however, not the only way in which the disposition of the striæ may be made to vary. In some gases at suitable pressures an increase in the strength of the current used, or in the quantity of electricity discharged through the tube, reduces the number of the striæ, and to some extent shortens the column by drawing or driving the striæ one by one into the positive terminal. In such a case it also increases their mutual distances in the same manner as if they were threaded on an elastic string. In other gases the reverse is the case. Thus, in this sulphide of hydrogen tube, the striæ in the column are numerous and crowded while the machine is in rapid motion. As the speed is diminished the striæ recede from one another, until only a few lingering specimens are left, separated by the broad dark and mysterious spaces which you now see.

The long continuance of the discharges from the induction coil afford an opportunity of examining the various phases of striæ during their existence. The details of the instrumental arrangements, as well as other particulars of the observations, have been elsewhere described; but the main features observed may be apprehended by the illustrations subjoined.

Fig. 7 represents the appearance of (in the mirror) a carbonic-acid tube with the slit attached. This tube, viewed by the eye, shows flake-like fluttering striæ, with a slight tendency to flocculency near the head of the column. The commencement of the discharge is at the right hand, and the negative terminal at the top. The drawing fairly represents the appearance of the upper part or head of the column of striæ during one complete coil-discharge. When the battery-surface exposed is small, the whole consists of, first, three or four columns of striæ of decreasing length, and afterwards of an almost unbroken field of striæ. Each of the initial columns is perfectly stratified; and the same disposition of striæ prevails throughout the entire discharge. The striæ which fill the main part of the field present a proper motion, that is a motion along the tube during their period of existence, usually steady and towards the positive. In this case it is nearly uniform, but slightly diminishing towards

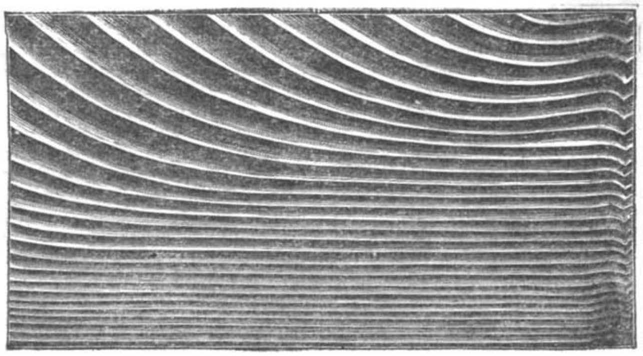

Fig. 8.

the end. These striæ are for the most part unbroken, but are occasionally interrupted at apparently irregular intervals. When the battery-surface is increased, the elementary striæ are more broken, and near the head of the column the interruptions occur as in the figure.

Fig. 8 represents the discharge in a hydrogen-tube of conical form, the diameter of which varied from capillary size to half an inch, the capillary end being at the bottom. The positive terminal is at the top. The principal interest of this tube consists in showing the influence of diameter upon the velocity of proper motion. The wider the tube the freer, it seems, the striæ are to move.

The same fact may be observed by comparing tubes differing in diameter, but in other respects the same; but the conical tube brings out the fact in the most striking manner.

Fig. 9 represents a chloroform-tube, in which a piece of

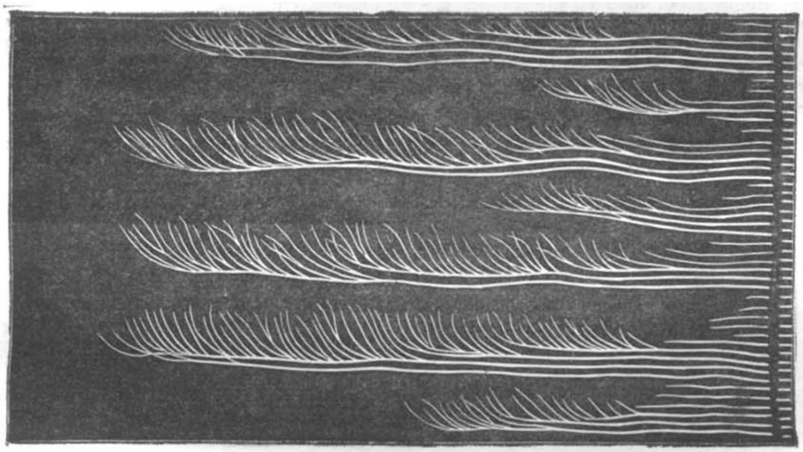

Fig. 9.

cotton-wool had been inserted with a view of ascertaining whether any motion would be communicated to it by the current. This proved to be the case; but I do not attempt here to describe the phenomenon. To the unassisted eye the discharge was extremely brilliant; it passed in a column not quite straight, but in a writhing, snake-like curve, with flaky striæ at intervals through its length. When viewed in the mirror the striæ were seen to spread themselves out with slight, but irregular, proper motion. With an increased battery-surface, or with a greater number of cells, but more notably with the latter, not only were the striæ lengthened, but from several of the long elementary striæ shorter ones were thrown out nearly at right angles to the former. These were of short duration, and had great proper motion. The general appearance of these compound striæ was that of branches of fir trees, the twigs of which represented the permanent striæ, and the leaves the secondary.

(*To be continued.*)

SOCIETIES AND ACADEMIES

Paris

Academy of Sciences, Sept. 19.—M. Wurtz in the chair.—The president gave a welcome to the foreign members of the International Congress of Electricity who were present, including Clausius, Clifton, Du Bois Reymond, Everett, Förster, Helmholtz, Kirchhoff, Melsens, Spottiswoode, Siemens (William and Werner), Smith, Stas, Thomson, Warren De La Rue, and Wartmann.—The following papers were read:—On the relative resistances that should be given, in dynamo-electric machines, to the active bobbins, the inductor electro-magnets, and the interior circuit, by Sir William Thomson.—On experiments made in 1826 on electric currents by lightning far from the place of observation,